

## **FINAL REPORT(March 12, 2001)**

### **PRELIMINARY CONCEPTUAL DESIGN REVIEW OF THE NPDGAMMA EXPERIMENT HYDROGEN TARGET AT THE MANUAL LUJAN SCATTERING CENTER (LANSCE-12)**

#### **INTRODUCTION**

The npdgamma experiment, which will run on Flight Path 12 at the MLNSC, requires a 20-liter liquid para-hydrogen target. The target has to be safe to operate, meet all MLNSC operational and safety requirements, and also achieve the experimental goals. The purpose of the meeting on May 10, 1999, was to conduct a preliminary conceptual design review of the target with regard to safety.

#### **COMMITTEE MEMBERSHIP AND CHARTER**

The Committee members were:

Roger Klaffky (chairman): LANSCE-12 Deputy Group Leader and Experimental Area Manager.

Frederick Edeskuty: Consultant. 49 years experience in all aspects of cryogenics and hydrogen safety and operations. Member of numerous cryogenic and hydrogen safety review committees, including Oak Ridge National Laboratory HFIR hydrogen moderator.

Dallas Hill: ESA-EPE Staff Member. Member of LANL Compressed and Liquefied Gas Safety Committee. 13 years experience with cryogenics and hydrogen.

John Jarmer: LANSCE-7 Staff Member. 20 years experience in cryogenics, low temperature research and dynamically polarized targets. Organized safety reviews of nuclear physics experiments at LAMPF and APT/A6 irradiation experiments at LANSCE.

Patrick Kelley: LANSCE-1 Staff Member. 15 years experience in cryogenics, including helium refrigeration, cryostat design, and superconducting magnet technology. Presently Task Leader for APT SRF ED&D Cryogenics and Acting Manager of the LANSCE-1 SRF Laboratory.

Trevor Lucas: Oak Ridge National Laboratory. Cryogenics engineer. 31 years experience in all areas of cryogenics. Presently in charge of design and construction of supercritical hydrogen moderator systems for the High Flux Isotope Reactor (HFIR) and the SNS spallation source.

Albert Prodell: Brookhaven National Laboratory. Physicist. 43 years experience in cryogenics beginning with LH2 bubble chambers. Presently in charge of cryogenic test facilities supporting RHIC project and LHC work at BNL. Chairman of the BNL Cryogenic Safety Committee.

William Schneider. Jefferson Lab. Senior Mechanical Engineer with over 40 years experience at two National Labs (BNL and Jefferson Lab). Designed , built and operated cryogenic systems servicing accelerators and detectors for nuclear research.

The Committee was assisted by:

Jan Novak: Consultant. Member of the LANL Compressed and Liquefied Gas Safety Committee. 37 years experience with hydrogen and cryogenics

The Committee was asked to:

Provide an independent review of the hydrogen safety aspects of the liquid hydrogen target system of the npdgamma experiment at LANSCE-12 with the priorities of protecting people (highest), protecting equipment and providing reliable operation.

Provide an overall assessment of and recommendations for improvement of the proposed hardware, procedures and facilities, including such aspects as design, controls, instrumentation, interlocks, safety systems, ease of operation and reliability.

Review a list of possible failures and comment whether each has been adequately represented and consequences correctly assessed, if the proposed mitigation method is adequate, if there is a better mitigation method, and if any failures have been overlooked.

Comment on whether all physical phenomena or physical behaviors with significant safety or operational consequences have been adequately considered.

Comment on any other safety or operational issues.

## **AGENDA AND DESCRIPTION OF THE TARGET SYSTEM**

The Committee met on May 10, 1999 in the LOB building, TA-53, Los Alamos National Laboratory.

The review began with a presentation by Dave Bowman (Spokesman) on the experimental goals. The experiment will measure the parity-violating gamma asymmetry in the capture of polarized cold neutrons by para-hydrogen in the  $n + p \rightarrow d + \gamma$  interaction. The weak interaction breaks the parity symmetry with  $5 \times 10^{-8}$  more gammas going up than down when the spin of the neutron is reversed. To obtain the proper statistics [systematic errors  $< 5 \times 10^{-9}$ ] there will have to be  $1 \times 10^{17}$  gammas detected, which will require approximately 8 months of running time and about 2 years on the experimental floor.

Mike Snow (Indiana University) gave a description of the target requirements and limitations. The target will have a 20 liter volume (30cm long with a 15 cm radius). The beam heating will be approximately 1 microwatt uniformly distributed through the target. Scattered neutrons will be captured by a Li6-rich blanket material before reaching the CsI gamma detectors. The target filling time takes several days, during which time access to the cave will be required. Reliable operation is expected using a mechanical refrigerator. Specifications for a CVI CGR511 refrigerator were presented.

Jan Novak presented the proposed target design parameters and safety features (Appendix I). Also an analysis of the possible failure modes of the target system (which Jan Novak and Bill Schneider prepared) were presented (Appendix II). A preliminary target design was also presented by Jan for the Committee's review (Figure 1). Jan pointed out that if all of the liquid hydrogen were to dump into the target cave (volume of 60 cubic meters), then there would be a 1/3 hydrogen gas/air mixture which is potentially explosive. The explosive force would be equivalent to approximately 75 lb of TNT, although the hydrogen would burn differently. The strategy used in the target design is to make all the jackets strong, to surround the target with a helium jacket in the cave, and to install redundant relief valves and rupture disks on each hydrogen gas inlet and outlet.

## **RECOMMENDATIONS FOR THE NPDGAMMA LIQUID HYDROGEN TARGET, CAVE, AND SERVICE AREA**

### **1. Target Cave Recommendations**

- a. There should be an oxygen monitor to permit personnel access into the cave.
- b. The cave will be ventilated according to the fire protection code NFPA 58. The LANL Fire Marshall will be contacted to determine the required ventilation specifications and if electrical equipment can be in the cave in an air environment.[See attached 7/27/99 e-mail from James Streit, LANL Fire Protection]. An explosion-proof fan should be used to ventilate the cave.
- c. If electrical equipment can be in the cave in an air environment, then there should a hydrogen monitor that will automatically shut off cave electrical equipment if hydrogen is detected at 10 percent of the lower explosive limit (LEL).
- d. An analysis should be performed on the effect of an explosion on the cave structure and surrounding equipment. Consideration should be given to the installation of blow-out panels.

### **2. Liquid Hydrogen Target Recommendations**

- a. The conceptual design procedure for sizing the hydrogen exhaust lines using the Smith and Williamson Bates Informal Report 90-2 was considered to be acceptable. Another reference on the design of hydrogen vent systems is the CGA publication CGA-6-5.5-1996 entitled "Hydrogen Vent Systems".
- b. The maximum allowable working (internal) pressure will be 4 times the operating pressure. The Committee recommends a room temperature pneumatic test at 1.25 times the MAWP. If possible, a hydrostatic test at 1.5 times the MAWP is preferable.
- c. There should be a summary design document that can be reviewed. This document should demonstrate that the vent paths are consistent with this MAWP in case of a target failure.
- d. All vessels should be designed and constructed to the ASME boiler/ high pressure code, Section VIII Division 1. The piping should have both physical and chemical certifications.
- e. All pressure vessels should be designed to withstand a differential external pressure of 2 atmospheres.
- f. In an emergency, the liquid hydrogen will be expelled using pressurized helium gas.
- g. The vacuum jacket should surround the entire length of the hydrogen supply and vent lines inside the helium jacket, and should extend to the outside of the cave. A total pressure interlock should be used on the vacuum jacket to dump the liquid hydrogen target and to shut off electrical power to equipment in the cave. Since the vacuum jacket is surrounded by liquid hydrogen and helium, the pressure will rise during a leak (water vapor will freeze).
- h. The dynamic structural integrity of the target system should be analyzed (natural frequencies; support of shields, target and detector, ..) If possible, the design should be for greater than 100 Hz.
- i. Either 6061 aluminum or copper-clad zirconium may be used for the target. Activation of the copper should be considered from an ALARA standpoint. Activation of all components should be considered as well as the possible exhausting of radioactive materials ( tritium, or spallation products). An engineering note should demonstrate that there would be no significant release of these materials.

- j. The pressure drop across the catalytic converter should be investigated since this is the maximum restriction in this potential vent line.
- k. There should be redundant relief valves and rupture disks ( 2 of each, in parallel) on all lines that can be overpressurized. There should be non-condensable helium gas downstream of these valves and disks to prevent air from condensing in the target.
- l. Since pump failure is a common problem, a recirculating hydrogen refrigerator is preferable to a pumped system
- m. Details of the superinsulation should be specified. Does it extend all the way up the piping to the catalytic converter/heat exchanger?

### 3. The Gas Handling System

- a. There should be a vented tent over the gas handling equipment with an explosion-proof fan.
- b. The tent enclosure should be designed so that it can not generate static charge. The tent will be vented to the outside of ER2 ( Building MPF-30).
- c. Hydrogen bottles should be located outside the ER2 building. The manifold for the bottles should only have sufficient ports to handle the number of bottles necessary to provide the system inventory, and no more.
- d. All electrical wiring and equipment inside the tent must be in accordance with Article 501 of the NFPA, National Electrical Code [see attached 7/21/99 communication(Appendix III) from James Streit, LANL Fire Protection.concerning fire protection for the LH2 target] A useful reference entitled "Electrical Installations in Hazardous Locations" is on the NFPA website.

### 4. Other Recommendations/Comments

- a. A hazard analysis [HCP] of the overall system should be performed. This analysis should address training issues, procedures for normal and abnormal operations including purging, start-up, gas bottle changes, leak detection, alarms, shutdown, emergency situations and ventilation. Interface issues to LANSCE -6, LANSCE-7, and LANSCE-12 should be addressed with regard to status indicators and emergency response. The requirement for a Target Watch needs to be addressed as well. There must be interlock test procedures for detectors, relief devices, alarms, etc, on a regular basis to recertify the system.
- b. Since the 1L Target cryot vessel is now considered a Category III Nuclear Facility it must be demonstrated that a hydrogen target explosion can not create projectiles or a shock wave capable of rupturing the cryot vacuum window ( it should be assumed that the flight path shutter is open during the explosion).
- c. The Committee needs a list of collaborators with their addresses, institutions, expertise and responsibilities on the experiment.
- d. To identify design problems at an early stage, there should be timely reports to the Committee.
- e. A design book ( with appropriate QA) should be started for the target documentation.
- f. The Committee notes that Jan Novak and Bill Schneider carried out a thorough analysis of the failure modes (Appendix II).

- g. There should be a pre-fabrication conceptual design review, followed by an operational safety review to look at detailed checklists and operational procedures. The LANSCE-12 Change Review Committee should also review the overall flight path layout, interface to adjacent flight paths, shielding, etc.